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Design and Simulation of a Chopper Series for a Photo-Voltaic Generator Functioning at its Maximum Power

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Abstract— Static converters are used in various fields of the conversion of electrical energy. The significant development of electric power switches and variety of design techniques of control and regulation circuits provide very advantageous solutions for the congestion, reliability, performance and maintenance of converters. This work focuses on the study and simulation of a chopper Series, and its association with a photovoltaic generator for the purpose of a Maximum Power in Operation issued by the latter. The principle of the chopper control is based on the variation of the duty ratio, based on a percentage of the open circuit voltage of a solar cell driver. The operation control system helps the photovoltaic system to function at its maximum power.

Keywords— Static converter, Chopper, Thyristor, Control circuit, Photovoltaic generator, Maximum power point.

I. Introduction

The optimization of photovoltaic generators performance and congestion perspective requires rigorous design methods, and the use of control systems and distribution of electrical energy more appropriately (Salameh, 1991; Schaefer, 1984 ;Issaadi, 2006). The technique of Maximum Power Point supplied by a photovoltaic generator is based on the introduction of a chopper between the generator and the storage battery or between the generator and the load directly (Merat, 1984; Séguier 1987; Champenois 1988; Dalmasso, 1988; Lander, 1989). The use of a thyristor-based on a converter allows a high power application, hence the interest of a tracking system of the maximum power point, which revolves around a dedicated control room (Schaefer, 1984; Salameh, 1991; Salas, Olias, Barrado and Lazaro, 2006; Gori, 2011; Azdani, 2009; Merahi, 2010; Benkhelil et Gherbi, 2011; Djafour, 2014). The principle of control is to vary the value of the duty ratio based on a fraction of the open circuit voltage of a solar cell pilot (image of the voltage at the maximum power point). A switching power supply is essentially a DC-DC converter to control the amplitude of the output voltage (Fogelman, 1982; Champagne, 1988; Won and Kim, 1994; Hsiao and Chen, 2005; Tahri et Benyoucef, 2010; Ait-Cheikh, 2007). As in any power electronics, semiconductor components used in electronic switch to maximize yield. The use of switching power transistors limits the chopping frequency, but the use of power MOS transistors and thyristors raises this limit, which greatly reduces component size (Raymon, 1983; Makhlouf, 2006). The use of auxiliary thyristors in the logic using circuit switching defused the main thyristor as quickly as we wish and therefore provides for low output voltages of the low currents (very interesting case for engine starting system series excitation) (Ramirez, 1980). In the low power range at medium power, we often need a continuous supply which has negligible ripple alternative but adjustable amplitude, however. For such applications, are used to power divisions (Agati, 1997). Closing and rapid opening of the switch gives a chopped voltage between the source and level of zero. This voltage is applied to an LC filter which smooth and applies a level substantially constant voltage to the load. Cutting (opening / closing) fast input voltage controls the output voltage that the average voltage output is a function of the duty cycle (Koutroulis, Kalaitzakis and Voulgaris, 2001; Hohm and Ropp, 2003; Calderon, 2006; Park, Ahn, Cho and Yu, 2006; Femia, Petrone, Spagnuolo and Vitelli, 2010; Poshtkouhi, Palaniappan, Fard and Trescases, 2011; Pilawa-Podgurski Robert, Perreault, 2013). The power circuit of the chopper being known, the aim of this study is to propose a

control circuit for controlling the switches by implementing this system in software to visualize the operation curves. This article on the study and the simulation of a series chopper for operation at maximum power from the PV array and its application in the case of the direct association of a DC motor of a submersible pump Type series in its joints, first presents the material and methods title that shows in detail the control circuit of a switching power supply, then the title results and discussion and finally concluded.

II. Materials and Methods

II. 1 Materials

As part of this work, we used the Proteus Version 8.1 software was used for the simulation.

II.2 Methods

II.2.1 The switching chopper principle

Priming the main thyristor Th_1 should not take place before the load capacitor C_d and reversing the polarity at its terminals. Priming of the auxiliary thyristor Th_2 creates a brief current which ensures the charge of the capacitor C_d in the supply voltage U_e. Thyristor Th_2 turns off by itself when the current I_c is zero, booting the second auxiliary thyristor Th_3, ensures polarity reversal of the capacitor Cd through the inductance L_d. The main thyristor Th_1 can be engaged from time t_2. To lock, simply start the auxiliary thyristor Th_2. The frequency of the ripple applied to the L_2-C_2 output filter is very high; as L_2 and C_2 values can be low, while allowing to greatly reduce the ripple. The diode provides a path to direct current in the charging coil when the switch is open. Can control the magnitude of the charging voltage to any desired level.

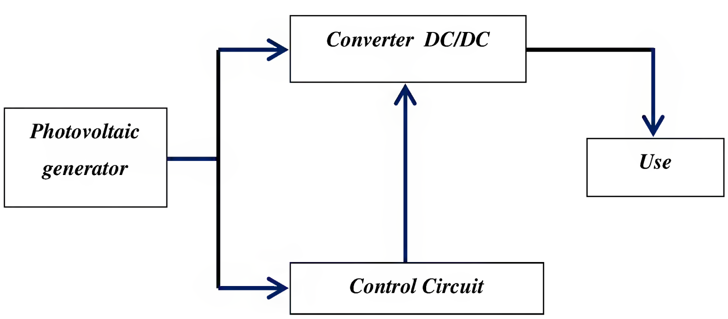

Figure 1: Block diagram General of a series chopper.

II.2.2 Control circuit chopper

The principle of the control circuit is to generate the necessary signals to the Thyristor firing, while observing the conditions of synchronization pulses during normal operation. The control signals resulting from the comparison of a saw tooth wave at a predefined reference voltage (case of Th_2 and Th_3) and a variable reference voltage (case Th_1).

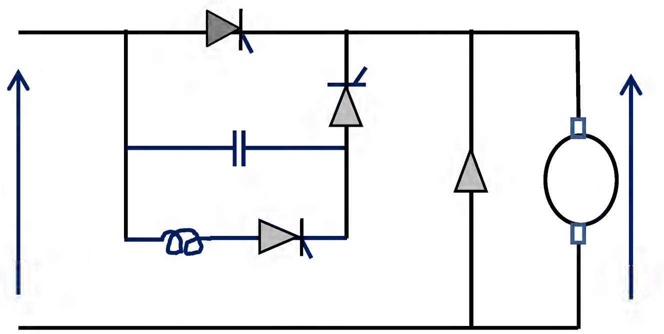

Figure 2: Chopper series.

The equation governing the oscillating circuit (Ld, Cd) is:

$U_{Cd} + L_d C_d\, d^2U_{Cd} / dt^2 = 0$

The solution of this equation is of the form:

$U_{Cd}\,(t)= U_m \cos\omega t$ where $\omega^2 L_d C_d = 1$

The capacitor requires a current:

$I_{Cd}(t)=C_d d(U_{Cd})/dt$

This transitional period lasts a half period $T_d/2= 2\omega/2=\omega$

Hence at this point we polarity reversal:

$U_{Cd}(t_2)=U_e \cos\omega t_2=U_e \cos\pi =-U_e$

The main thyristor Th_1 can be engaged from time t_2. To lock, simply start the auxiliary thyristor Th_2.

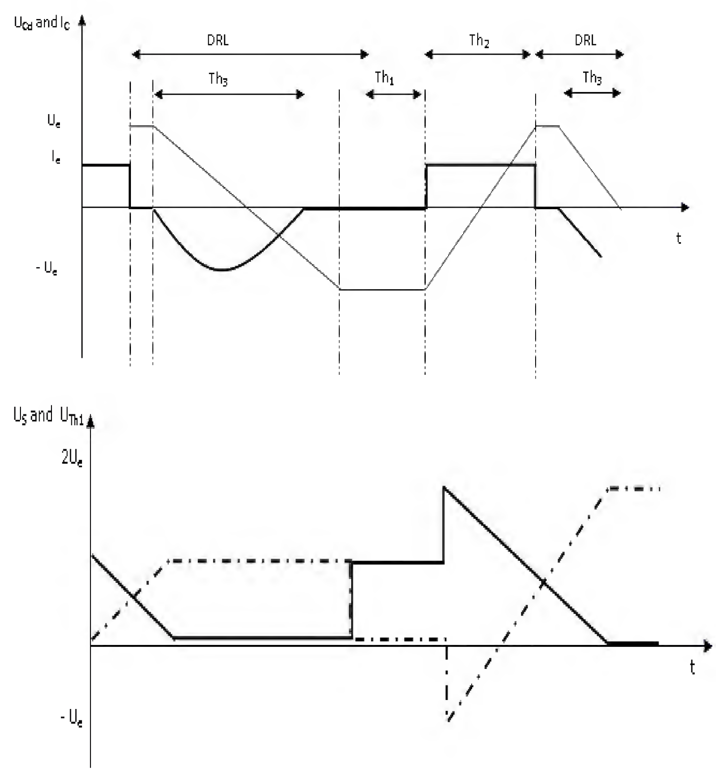

Figure 3: Timing diagrams of voltages and currents of the series chopper.

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II.2.3 Dimensionnement extinguishing system

The value of C_d capacity must be chosen so that the protection time (t_f) is guaranteed to put out the maximum current Is debited through the chopper. 't_f' is determined by the equation defining the voltage across the main thyristor during the switching phase.

$U_C = U_{Th1} = I_S\,(t-t_4) / C_d - U_e$

U_{Th1} remains negative until time t_5 (as $t_4 - t_5 = t_C$)

$t_f = C_d\, U_e / I_S$

II.2.4 Control circuit chopper

The principle of the control circuit is to generate the necessary signals to the thyristor firing, meanwhile observing the conditions of synchronization pulses during normal operation. Cancels the signals resulting from the comparison of a sawtooth wave voltage to a predefined reference (case of Th_2 and Th_3) and a variable reference voltage (case of Th_1).

III. Experimental results

The following figures show the different timing of the control circuit implemented in the Proteus software to visualize the evolution of different voltages.

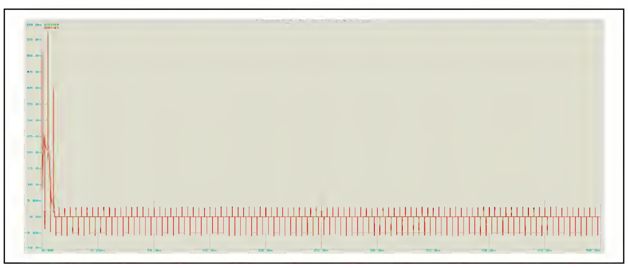

Figure 4: Terminal voltage of the main thyristor **Th_1.**

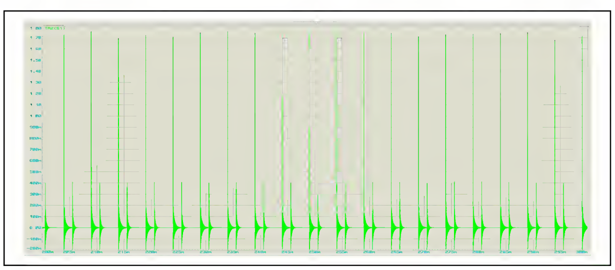

Figure 5: Terminal voltage of the auxiliary thyristor **Th_2.**

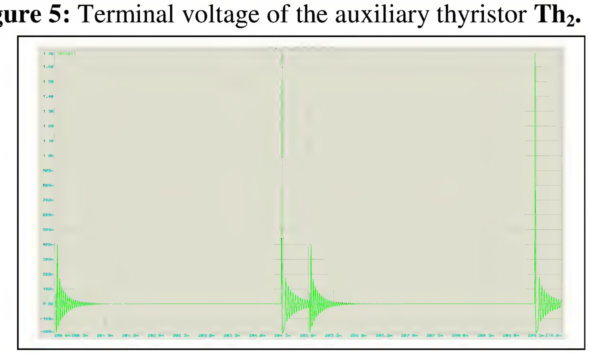

Figure 6: Terminal voltage of the auxiliary thyristor **Th3.**

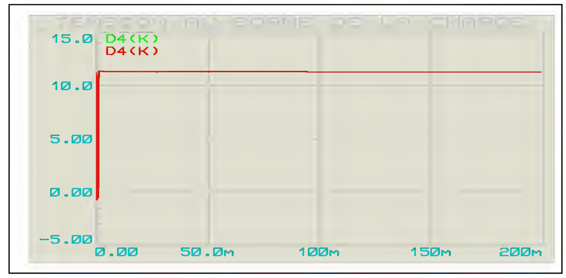

Figure 7: Voltage across the load for a duty ratio α = 0.7.

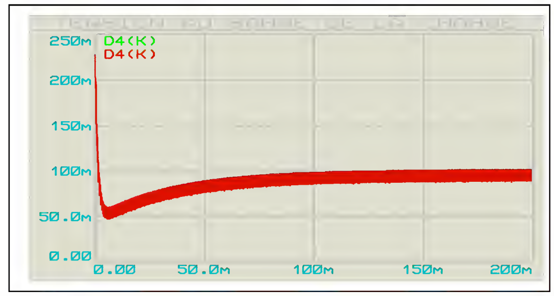

Figure 8: Voltage across the load for a duty ratio α = 0.3.

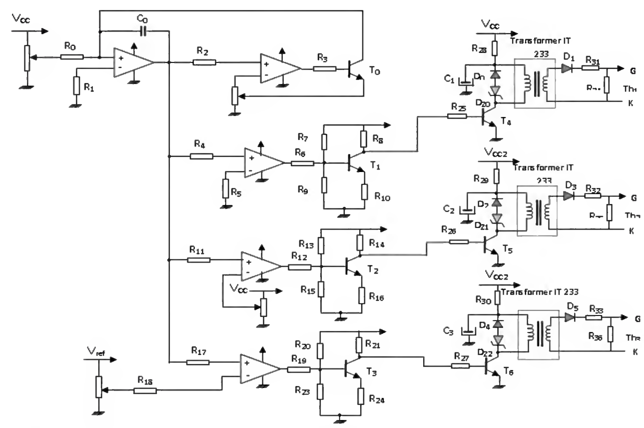

Figure 9: Chopper control circuit series for a PV generator.

IV. Conclusion

The study and the simulation of a series chopper for operation at maximum power of a PV generator satisfactory results. Of cause, it would be boring testing the system on real load to assess the direct association of the solar generator with a DC motor. It will identify opportunities to use manual control for engine start (starting current limitation) and then switch to a standalone mode, once the duty ratio reaches a certain value and see how to make regulation the duty cycle for proper operation of the pump.

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xxxviii. ANNEX. A chopper control circuit series for a photovoltaic generator functioning at its maximum power.